ELECTRICAL LOSSES IN THE ELECTRICITY DISTRIBUTION NETWORKS WHEN CONNECTING NEW GENERATOR POWER

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ABSTRACT. The report considers the possibility of connecting new generating powers in a cascade of HPP. The flow distribution of powers at different powers of the power plants is determined, as well the voltages at the connection points in the power supply scheme of the power lines. The losses of power and electricity under different operating conditions are determined analytically.

Keywords: electrical losses

ЗАГУБИ В ЕЛЕКТРОРАЗПРЕДЕЛИТЕЛНИТЕ МРЕЖИ ПРИ ПРИСЪЕДИНЯВАНЕ НА НОВИ ГЕНЕРАТОРНИ МОЩНОСТИ

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РЕЗЮМЕ. В доклада се разглежда възможността за присъединяване на нови генераторни мощности в каскада от ВЕЦ. Определено е потокоразпределението на мощностите при различни мощности на централите, а така също и напреженията в точките на присъединяване в електроснабдителната схема на електропроводите. Аналитично са определени загубите на мощност и електроенергия при различни условия на експлоатация.

Ключови думи: електрически загуби

An analysis was made of the possibility for connection of "Opletnya" MHPP with a capacity of 2,6 MW to the existing 20 kV power lines "Milanovo" and "Izdrinets". "Lakatnik" MHPP and "Svrazhen" MHPP, each of them with a capacity of 3,2 MW, are connected to the same power lines. The single-line diagram is shown in fig. 1. The flow distribution of powers at different generated powers of the power plants is determined, as well the voltages at the connection points in the power supply scheme of the power lines.

As output data additionally are given:

- voltage of the busbars at substation Bov – 20,5 kV;
- minimum power factor of the connected consumers - cosφ = 0,90;
- power factor of the connected power plants - cosφ = 0,95 ÷ 1,00.

In the article are discussed four options of connecting.

First option: the two power lines are in parallel at both ends

In this variant, a case is considered, in which the two power lines are considered as single, but with a cross sectional area of the conductors in the main feed, equivalent to ACSR 190 mm2 (2 x ACSR 95).

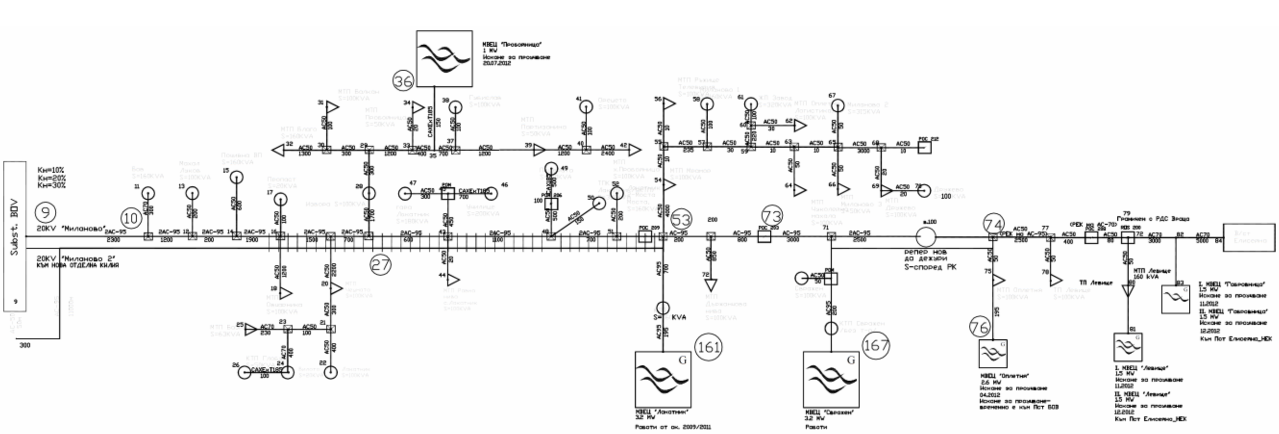

Fig. 1. Single-line diagram.

The calculation model also envisages the operation of a new MHPP "Proboynitsa" with a power of 1 MW. In the scheme considered this way, three values of the generated power and two values of the electric energy consumed by the consumers are set. The results of the calculations at some specific points are shown in tables 1 to 4.

From table 1 obviously the generated power at any moment exceeds the consumed by the consumers connected to the power network and the flow of power along the main power line will be in the direction of substation Bov. From the point of view of the allowable current load, the conductors will not be overloaded.

Table 1 - *power lines are in parallel at both ends 100% generator power, Kn = 10%, cosφ = 0,95*

Losses	ΔP, kW	ΔQ, kVAr
	467	519

Point	Generator power kW	Difference kW	Main feed power kW	Current, A	U, kV
9					20,50
10	10000	9534	466	269	20,87
27	9000	8622	379	243	21,76
36	1000	1000		28	21,75
53	9000	8810	191	248	22,13
161	3200	3200		90	22,11
167	3200	3200		90	22,74
74	2600	2590	10	73	23,03
76	2600	2600		73	23,05

Power losses in the entire power network (including to consumers) will be ΔP = 467 kW and ΔQ = 519 kVAr. The voltage at the connection points (including in the connections of the consumers) will be significant, as the maximum exceedance will be 2,55 kV (at busbar voltage in the substation U = 20,5 kV). This will be 15,25% higher, compared to the nominal voltage. Obviously even if the additional terminals of the transformers are used (± 5%), the end users will receive a significantly higher voltage than the allowable one.

Table 2 - *power lines are in parallel at both ends 50% generator power, Kn=10%, cosφ =0,95*

Losses	ΔP, kW	ΔQ, kVAr
	110	121

Point	Generator power kW	Difference kW	Main feed power kW	Current, A	U, kV
9					20,50
10	5000	4534	466	128	20,68
27	4500	4122	379	116	21,10
36	500	500		14	21,10
53	4500	4310	191	121	21,28
161	1600	1600		45	21,27
167	1600	1600		45	21,59
74	1300	1290	10	36	21,73
76	1300	1300		37	21,74

In this mode, the maximum voltage increase will be 1,24 kV. This is 8,7% higher, compared to the nominal voltage. The highest voltage will be in MTP "Derzhanchova Niva" with a value of 21,60 kV, or 8,00% higher than nominal. For the other transformers the voltage will be in the range from 20,68 kV to 21,25 kV. This voltage will be relatively acceptable, if the transformers are switched to voltage 21 / 0,4 kV .Power losses in the entire power network (including to consumers) will be ΔP = 110 kW and ΔQ = 121 kVAr.

Table 3 - *power lines are in parallel at both ends 30% generator power, Kn =10%, cosφ =0,95*

Losses	ΔP, kW	ΔQ, kVAr
	29	33

Point	Generator power kW	Difference kW	Main feed power kW	Current, A	U, kV
9					20,50
10	3000	2534	466	71	20,60
27	2700	2322	379	65	20,84
36	300	300		8	20,84
53	2700	2510	191	71	20,94
161	960	960		27	20,94
167	960	960		27	21,03
74	780	770	10	22	21,10
76	780	780		22	21,10

In this mode the maximum voltage increase will be 0,60 kV. This will be 5,5% higher, compared to the nominal voltage. In MTP "Derzhanchova Niva", will be the highest voltage with a value of 21,04 kV, or 5,02% higher than nominal. For the other transformers, the voltage will be in the range of 20,60 kV to 20,91 kV. This voltage will be within the variable range of the transformers. Power losses in the entire power network (including to consumers) will be ΔP = 29 kW and ΔQ = 33 kVAr.

Table 4 - *the power lines are in parallel at both ends 30% generator power, Kn =30%, cosFi =0,95*

Losses	ΔP, kW	ΔQ, kVAr
	17	18

Point	Generator power kW	Difference kW	Main feed power kW	Current, A	U, kV
9					20,50
10	3000	1603	1397	45	20,56
27	2700	1565	1136	44	20,72
36	300	300		8	20,72
53	2700	2129	572	60	20,81
161	960	960		27	20,80
167	960	960		27	20,89
74	780	750	30	21	20,96
76	780	780		22	20,96

Voltages, similar to the previous one mode are obtained. That shows, increasing the power, consumed by consumers will reduce the voltage at their connection points, but their relative value is small. As a general conclusion, it can be noted, that the reduction of the generated and the increase of the consumed electricity, will increase quality of the power supply. Power losses in the entire power network (including to consumers) will be ΔP = 17 kW and ΔQ = 18 kVAr.

Option 2 - Lakatnik to Izdrinets, Svrazhen and Opletnya to Milanovo

In the considered scheme are set three values of the generated power and two values of the electricity consumed by the consumers. The results of the calculations at some specific points are shown in Tables 5 to 8.

Table 5 - *Lakatnik to Izdrinets, Svrazhen and Opletnya to Milanovo 100% generator power, Kn =10%, cosφ =0,95*

Losses	ΔP, kW	ΔQ, kVAr
	442	498

Point	Generator power kW	Difference kW	Main feed power kW	Current, A	U, kV
9					20,50
10	6800	6334	466	150	20,92
27	6800	6422	379	153	21,92
53	5800	5610	191	158	22,40
161	3200	3200		90	21,72
167	3200	3200		90	23,01
74	2600	2590	10	73	23,35
76	2600	2600		73	23,38

In this mode, the maximum voltage increase will be 2,88 kV. This is 16,9% higher, compared to the nominal voltage. Obviously, this excess of the voltage will be unacceptable for consumers. The power losses in the entire power network (including to the consumers) will be ΔP = 442 kW and ΔQ = 498 kVAr.

Table 6 - *Lakatnik to Izdrinets, Svrazhen and Opletnya to Milanovo 50% generator power, Kn =10%, cosφ =0,95*

Losses	ΔP, kW	ΔQ, kVAr
	102	115

Point	Generator power kW	Difference kW	Main feed power kW	Current, A	U, kV
9					20,50
10	6800	6334	466	150	20,92
27	6800	6422	379	153	21,92
53	5800	5610	191	158	22,40
161	3200	3200		90	21,72
167	3200	3200		90	23,01
74	2600	2590	10	73	23,35
76	2600	2600		73	23,38

In this mode the maximum voltage increase will be 1.37 kV. This is 9,35% higher, compared to the nominal voltage. The highest voltage will be in the MTP "Derzhanchova Niva" with a value of 21,69 kV, or 8,45% higher than nominal. For the other transformers the voltage will be in the range of 20,69 kV to 21,35 kV. This voltage will be within the variable range of the transformers. Power losses in the entire network (including to consumers) will be ΔP = 102 kW and ΔQ = 115 kVAr.

Table 7 - *Lakatnik to Izdrinets, Svrazhen and Opletnya to Milanovo 30% generator power, Kn =10%, cosφ =0,95*

Losses	ΔP, kW	ΔQ, kVAr
	39	43

Point	Generator power kW	Difference kW	Main feed power kW	Current, A	U, kV
9					20,50
10	2040	1574	466	44	20,62
27	2040	1662	379	47	20,93
53	1740	1550	191	44	21,05
161	960	960		27	20,87
167	960	960		27	21,24
74	780	770	10	22	21,34
76	780	780		22	21,34

In this mode, the maximum voltage increase will be 0,84 kV. This is 6,7% higher, compared to the nominal voltage. The highest voltage will be in MTP "Derzhanchova Niva" with a value of 21,24 kV, or 6,2% higher than nominal. For the other transformers the voltage will be in the range of 20.62 kV to 21.02 kV. This voltage will be within the variable range of the transformers. Power losses in the entire power network (including to consumers) will be ΔP = 39 kW and ΔQ = 43 kVAr.

Table 8 - *Lakatnik to Izdrinets, Svrazhen and Opletnya to Milanovo 30% generator power, Kn =30%, cosφ =0,95*

Losses	ΔP, kW	ΔQ, kVAr
	25	27

Point	Generator power kW	Difference kW	Main feed power kW	Current, A	U, kV
9					20,50
10	2040	643	1397	18	20,55
27	2040	905	1136	25	20,70
53	1740	1169	572	33	20,78
161	960	960		27	20,86
167	960	960		27	20,96
74	780	750	30	21	21,06
76	780	780		22	21,07

In this mode, the maximum voltage increase will be 0,57 kV. This is 5,35% higher, compared to the nominal voltage. The highest voltage will be in MTP "Derzhanchova Niva" with a value of 20,97 kV, or 4,85% higher than nominal. For the other transformers the voltage will be in the range of 20,55 kV to 20,69 kV. This voltage will be within the variable range of the transformers. Power losses in the entire power network (including to consumers) will be ΔP = 25 kW and ΔQ = 27 kVAr.

Option 3 - Separation of generators on one power line and consumers on the other

This is the optimal mode for electricity consumers. For them, the received power will be from substation Bov, in which voltages at the connection points will depend on the voltage drop in the feed line and the busbar voltage in the substation. In particular, even if a new cell is not equipped and the two power lines are separated, practically the increase (decrease) of voltage at the point of connection of the two power lines will be negligible.

Table 9 - *Separation of generators on one power line and consumers on the other 100% generator power, Kn =30%, cosφ =0,95*

Losses	ΔP, kW	ΔQ, kVAr
	800	886

Point	Generator power kW	Current, A	dU %	ΔP kW	ΔQ kVAr	U kV
9	9000	253				20,50
27	9000	253	2,39	496	552	22,89
53	9000	253	0,77	159	177	23,65
53_1	3200	84	0,08	5	5	23,73
161	3200	90	0,02	2	2	23,75
200	5800	161	0,04	5	6	23,69
72		4	0,00	0	0	23,69
73	5800	162	0,16	21	23	23,85
71	5800	162	0,59	78	86	24,43
71_1	3200	86	0,01	1	1	24,44
167	3200	90	0,02	2	2	24,46
74	2600	72	0,11	6	7	24,54
75	2600	70	0,01	0	0	24,55
76	2600	73	0,03	2	1	24,57

The table shows, that at full power of the generators, the voltage will significantly exceed the nominal. In addition to the transformer for own needs to the respective power plants (items 53_1, 71_1, 75), MTP "Derzhanchova Niva" will also be at a higher voltage with a value of 23,69 kV. These voltages are unacceptable for the transformers and the consumers connected to them. In addition, the over-voltage protection of 20 kV feeders from the power plants (Uset = 22 kV) will be activated.

The power losses in power line will be ΔP = 800 kW and ΔQ = 886 kVAr.

Table 10 - *Separation of generators on one power line and consumers on the other*
30% generator power, Kn =30%, cosφ =0,95

Losses	ΔP, kW	ΔQ, kVAr
	117	130

Point	Generator power kW	Current, A	dU %	ΔP kW	ΔQ kVAr	U kV
9	4500	98				20,50
27	4500	98	0,92	74	82	21,42
53	1600	98	0,29	24	26	21,72
53_1	1600	30	0,03	1	1	21,74
161	2900	36	0,01	0	0	21,75
200		59	0,01	1	1	21,73
72	2900	4	0,00	0	0	21,73
73	2900	60	0,06	3	3	21,79
71	1600	60	0,22	11	12	22,00
71_1	1600	32	0,00	0	0	22,01
167	1300	36	0,01	0	0	22,02
74	1300	25	0,04	1	1	22,04
75	1300	22	0,00	0	0	22,04
76	2600	26	0,01	0	0	22,05

And in this case, the voltage increase will be higher than allowable. The power losses in power line will be ΔP = 117 kW and ΔQ = 130 kVAr.

Conclusion

The best option for power supply, is when the two power lines are in parallel and generator power is 30% (table 3 and table 4), even with the future connection of MHPP "Proboynitsa" with a power of 1 MW. In this option, the voltages at the individual points of the power network, as well as the electricity losses, will be the lowest.

"Option 2 - Lakatnik MHPP to Izdrinets, Svrazhen MHPP and Opletnya MHPP to Milanovo" is also a good option if the generators operate with 30% generator power at each of the power plants (Table 7 and Table 8). The voltages at the detached points of the power network will be within the permissible limits, and the losses of power and electricity will be in the same order, as in parallel operation of the power lines.